VOLUME II
FLYING QUALITIES

CHAPTER 1
INTRODUCTION TO FLYING QUALITIES

MARCH 1991
USAF TEST PILOT SCHOOL
EDWARDS AFB CA

TABLE OF CONTENTS

1.1 TERMINOLOGY 1

1.2 PHILOSOPHY OF FLYING QUALITIES TESTING 5

1.3 FLYING QUALITY REQUIREMENTS 6

1.4 CONCEPTS OF STABILITY AND CONTROL 9

1.4.1 Stability 9

1.4.2 Control 11

1.5 AIRCRAFT CONTROL SYSTEMS 11

1.6 SUMMARY 12

1.7 USAF TEST PILOT SCHOOL CURRICULUM APPROACH 13

BIBLIOGRAPHY 14

1.1 TERMINOLOGY

Flying Qualities is that discipline in the aeronautical sciences that is concerned with basic aircraft stability and pilot-in-the-loop controllability. With the advent of sophisticated flight control systems, vectored thrust, forward-swept wings, and negative static margins, the concept of flying qualities takes on added dimensions.

In aeronautical literature there are three terms bandied about which are generally considered synonymous. These terms are "flying qualities," "stability and control," and "handling qualities." Strictly speaking, they are not synonymous (1.1). An early publication by Phillips in 1949 defines flying qualities of an aircraft as those "stability and control characteristics that have an important bearing on the safety of flight and on the pilots' impressions of the ease of flying an aircraft in steady flight and in maneuvers" (1.2). The current US Navy flying qualities definition is similar except it relates stability and control characteristics to the total mission (1.4). The document now used by the USAF in specifying military flying qualities requirements, MIL-STD-1797A, <u>Flying Qualities of Piloted Aircraft</u>, provides the following definition: "Flying qualities encompass whatever is involved in flying the aircraft (and in piloting it on the ground) safely and in performance of operational missions from the point of view of the pilot" (1.3). Clearly then, the definition of flying qualities includes more than just stability and control characteristics. It should include, as a subset, aircraft handling qualities which relate directly to pilot opinion. The military standard, MIL-STD-1797A, is also "...intended to assure flying qualities for adequate mission performance and flight safety regardless of the design implementation, flight control system augmentation, or impact of other related subsystems" (1.3). **Successful execution of the total military mission then is the key to flying quality adequacy.**

The academic treatment of "stability and control" is usually limited to the interaction of the aerodynamic controls with the external forces and moments on the aircraft. Etkin defines "stability" as "...the tendency or lack of it, of an airplane to fly straight with wings level" and "control" as "...steering an airplane on an arbitrary flightpath" (1.5). This academic treatment sometimes excludes the forces felt and, especially, exerted on the cockpit controls by the pilot. "Handling qualities" is the term generally used to define this aspect of the problem. "Handling qualities" are defined by Cooper and Harper as "...those qualities or characteristics of an aircraft that govern the ease and precision with which a pilot is able to perform the tasks required in support of an aircraft role" (1.1, 1.6). Handling qualities are definitely pilot-in-the-loop

characteristics which affect mission accomplishment.

Stability and control parameters are generally derived from "open loop" testing, that is, from testing where an aircraft executes specific maneuvers under the control of an assumed "ideal programmed controller" or exhibits free response resulting from a more or less "mechanical" pilot input. The quantitative results are thus independent of pilot evaluation. Many parameters derived in this fashion such as damping and frequency of aircraft oscillation are assigned a "Level" of acceptability as define by the contents of Reference 1.3, MIL-STD-1797A. These "levels" of acceptability of an aircraft were derived from previous flight test experience. Their intent is to ensure adequate flying qualities for the design mission of an aircraft. Other parameters such as aircraft stability and control derivatives are obtained using parameter identification techniques such as the Modified Maximum Likelihood Estimator (MMLE). These flight test determined derivatives are used as analysis tools for flying quality optimization which occurs during developmental flight testing (1.7). The terms "stability" and "control" do not include the pilot-in-the-loop or man/machine interface.

Handling qualities, on the other hand, are generally determined by performing specifically defined operationally oriented tasks where pilot evaluation of both system task accomplishment and workload are crucial. In the terminology relationships shown in Figure 1.1, the pilot is considered to be in the "handling qualities" block. Pilot ratings defined by the Cooper-Harper Pilot Rating Scale (Figure 1.2) are frequently the results in this "closed loop" type of testing, although a few tasks (such as landing) are assigned a "Level" by MIL-STD-1797A. Handling qualities are currently evaluated at the AFFTC using precise pilot-in-the-loop tracking tasks. Two of these test methods are known as Handling Qualities During Tracking (HQDT) and Systems Identification From Tracking (SIFT) (1.6, 1.8, 1.9).

To complicate matters, sometimes "closed loop" tasks are required to gather stability and control data. An example is maneuvering stick force gradient, which required stabilizing on aim airspeed at high load factor. This is a "closed loop" task for the pilot, particularly if the aircraft has a low level of stability. Because of such complications and interactions between "stability," "control," and "handling qualities," the term "flying qualities" is considered the more inclusive term and is customarily used at the AFFTC to the maximum extent possible (1.1).

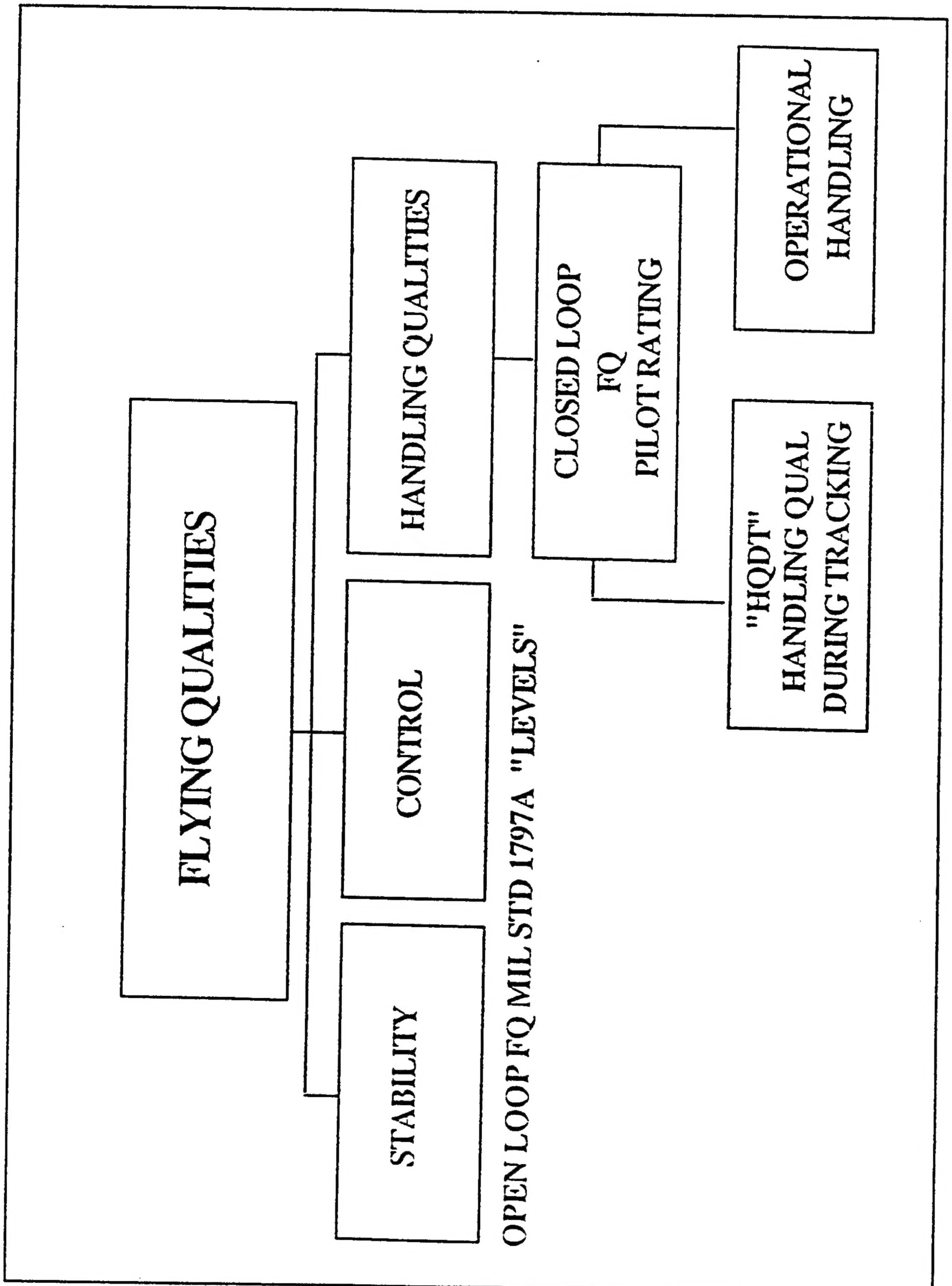

FIGURE 1.1. FLYING QUALITIES BREAKDOWN

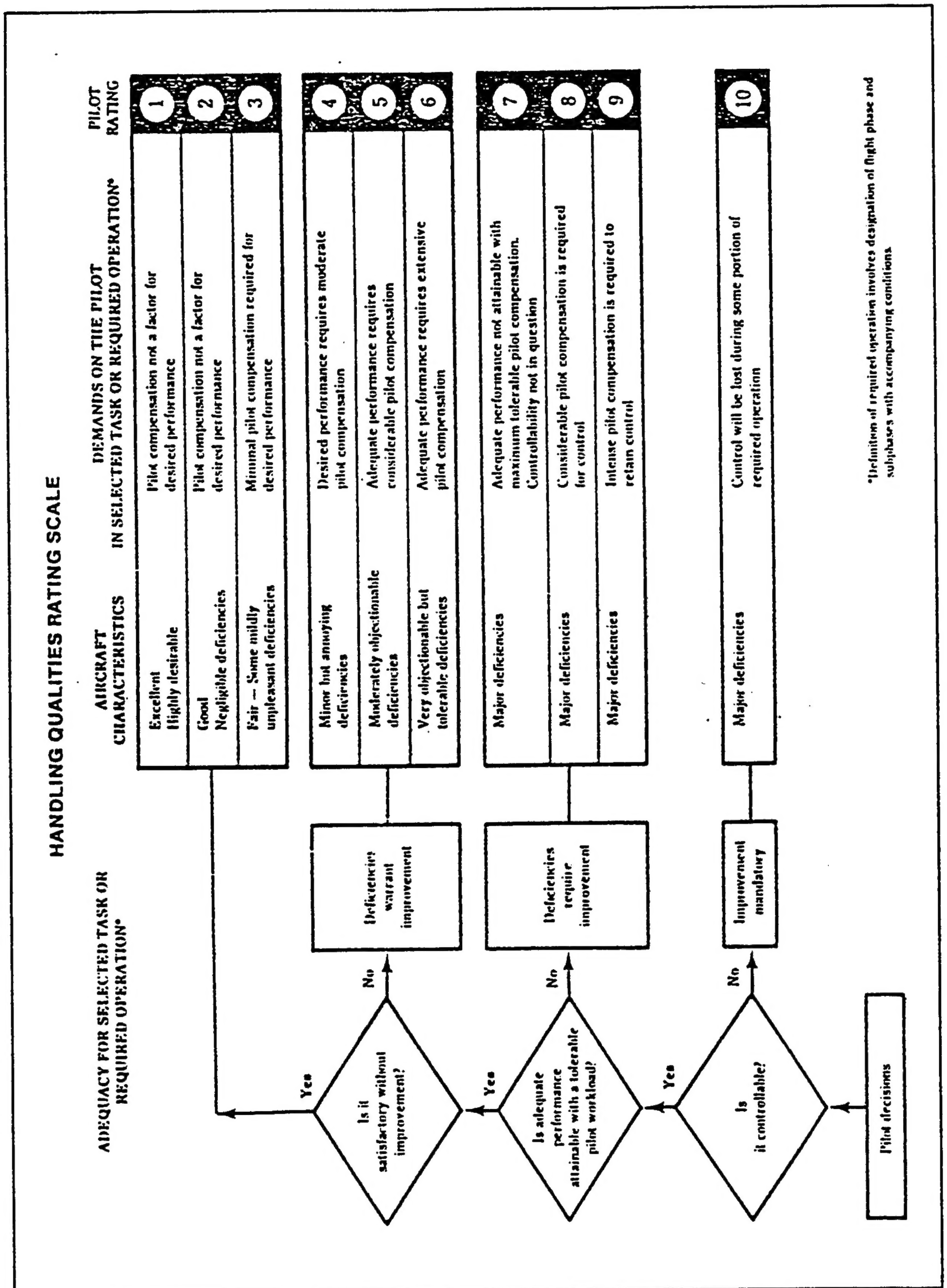

FIGURE 1.2. COOPER-HARPER PILOT RATING SCALE (1.6)

1.2 PHILOSOPHY OF FLYING QUALITIES TESTING

The flying qualities of a particular aircraft cannot be assessed unless the total mission of the aircraft and the multitude of individual tasks associated with that mission are defined. The mission is initially defined when the concept for a new aircraft is developed; however, missions can be completely changed during the service life of an aircraft. In the formulation of a test and evaluation program for any aircraft, the mission must be defined and clearly understood by all test pilot and flight test engineer members of the test team (1.4).

The individual tasks associated with the accomplishment of a total mission must also be determined before the test and evaluation program can be planned. Although individual tasks may be further subdivided, a military mission will normally require the pilot (crew) to perform the following tasks:

1. Preflight and ground operations
2. Takeoff and Climbs
3. Navigation
4. Mission Maneuvering/Employment
5. Approach and Landing
6. Postflight and Ground Operation

The tasks for which the "best" levels of flying qualities are required are the essential or critical tasks required by the total mission. For a fighter or attack aircraft performing air-to-air or air-to-ground maneuvers (and training for those maneuvers), the greatest emphasis must be placed on the flying qualities exhibited while performing these critical tasks. For a bomber or tanker aircraft, low level terrain following, or air-to-air refueling might be critical maneuvers. These tasks vary with aircraft mission. In any case, adequate flying qualities must be provided so that takeoff, approach, and landing maneuvers can be consistently accomplished safely and precisely (1.4).

The primary reason for conducting flying quality investigations then is to determine if the pilot-aircraft combination can safely and precisely perform the various tasks and maneuvers required by the total aircraft mission. This determination can often be made by a purely qualitative approach; however, this is usually only part of the complete test program. Quantitative flight testing must also be performed to:

1. Substantiate pilot qualitative opinion.
2. Document aircraft characteristics which particularly enhance or degrade some flying quality.
3. Provide data for comparing aircraft characteristics and for improving aircraft and simulator design criteria.
4. Provide baseline data for future expansion in terms of flight or center of gravity envelopes or change in aircraft mission.
5. Determine compliance or noncompliance with flying qualities guarantees, appropriate military specification/standards, and federal airworthiness regulations, as applicable.

A balance between qualitative and quantitative testing is normally achieved in any flying quality flight test evaluation program (1.4).

1.3 FLYING QUALITY REQUIREMENTS

In December 1907, the United States Army Signal Corps issued Signal Corps Specification 486 for procurement of a heavier-than-air flying machine. The specification stated, "During this trial flight of one hour it must be steered in all directions without difficulty and at all times be under perfect control and equilibrium." This was clearly a flight demonstration requirement (1.10). The Air Force Lightweight Fighter Request for Proposal in 1972, in addressing stability and control, specified only that the aircraft should have no handling qualities deficiencies which would degrade the accomplishment of its air superiority mission (1.11, 1.12). In response, the contractor predicted that the handling qualities of the prototype would "...permit the pilot to maneuver with complete abandon" (1.12, 1.13). The requirements placed on the Wright Flyer and the Lightweight Fighter contractor's flying quality predictions were remarkably similar. From these examples, one might assume that the art or science of specifying flying quality requirements has not progressed since 1907.

In the late 1930's, flying quality requirements appeared in a single but all encompassing statement appearing in the Army Air Corps designers handbook: "The stability and control characteristics should be satisfactory" (1.10).

In 1940, the National Advisory Committee for Aeronautics (NACA) concentrated on a sophisticated program to correlate aircraft stability and control characteristics with pilots' opinions on the aircraft's flying qualities. They determined parameters that

could be measured in-flight which could be used to quantitatively define the flying qualities of aircraft. The NACA also started accumulating data on the flying qualities of existing aircraft to use in developing design requirements (1.14).

Probably the first effort to set down an actual specification for flying qualities was performed by Warner for the airlines during the Douglas DC-4 development (1.14). During World War II, research branches of both the Army Air Corps and Navy became involved in flying quality development and started to build their own capabilities in this area. An important study headed by Gilruth, published in 1943, was the culmination of all of this work up to that time (1.15). This study was supplemented by additional stability and control tests conducted at Wright Field under the auspices of Perkins (1.16). Shortly thereafter, the first set of Air Corps requirements was issued as a result of joint effort between the Army Air Corps, the Navy, and NACA. At the same time, the Navy issued a similar specification. These specifications were superseded and revised in 1945 (1.10, 1.17). Perkins also published a manual which presented methods for conducting flight tests and reducing data to demonstrate compliance with the stability and control specification. This manual, published in 1945, is remarkably similar to, and is the forerunner of, the present USAF Test Pilot School Flying Qualities Flight Test Handbook (1.16).

Progress in the development of military flying quality specification is well documented in References 1.10 and 1.18. Work on MIL-F-8785 was started in 1966 and first published in August 1969 as MIL-F-8785B(ASG). It was revised in 1974 and again in 1980 when it was republished as MIL-F-8785C. The Background Information and User Guide for MIL-F-8785B(ASG) (1.18) explains the concept and arguments upon which the current requirements were based. Data reduction techniques recommended to determine military specification compliance are essentially those presently in use at the USAF Test Pilot School. The School was actively involved in the development of MIL-F-8785B(ASG), and was first used by students evaluating their data group aircraft (T-33A, T-38A and B-57) against specification requirements. MIL-F-8785C was first used by Class 81-A evaluating the KC-135, T-38, F-4 and A-7 aircraft.

The School also participated in development of MIL-F-83300 which places flying quality requirements on piloted V/STOL aircraft (1.19). Reference 1.20 is a companion background document for this specification. The short-lived helicopter test pilot training program at the School used MIL-F-83300 for evaluations of the H-13, UH-1 and Ryan XV-5 V/STOL simulator (1.21).

Military flying quality specifications were failures as "requirements." They were not used as amendments to contracts to serve as procurement compliance documents. Procuring activities usually wrote their own flying qualities requirements by extracting paragraphs from the specifications as they saw fit. After negotiations with the contractors, they would modify the requirements as necessary and include them in the contracts. Another approach used by procuring activities was to ask the contractors to pick the specification requirements they intended to meet and list them in their initial proposals. Both of these procedures left much to be desired.

The search for an alternative approach to the specifications went on for some time. The difficulty was in developing a physically sound approach which was acceptable to the military services and to those contractors who must design to the stated flying quality requirements (1.23). The Air Force Flight Dynamics Laboratory funded Systems Technology Incorporated to develop a new approach. The result was a flying quality Military Standard, MIL-STD-1797, published in 1987. This was a skeleton document consisting of incomplete requirements in verbal form which were to be completed by procuring activities using quantitative and qualitative criteria from an appendix. The appendix also included recommendations for criteria selection. When they were available, lessons learned were also provided in the form of discussions of aircraft which exhibited unsatisfactory flying quality characteristics when they failed to meet the military standard recommended criteria. Many of these discussions were taken from published military flight test reports. Unfortunately, this resulted in the document being restricted in distribution and subject to export control laws. The only use of MIL-STD-1797 in aircraft flying quality evaluation was done here at the School by Classes 88B thru 90A in flight tests of the T-38, F-4, A-7, KC-135 and UV-18 aircraft. The Air Force Flight Dynamics Laboratory made minor revisions to MIL-STD-1797 and published it in 1990 and MIL-STD-1797A. Class 90B was the first class at the School to use this revised standard in their evaluations of the T-38, F-4 and A-7 aircraft. It remains to be seen if (or how) it will be used by procuring activities.

Formal discussions of aircraft flying qualities almost always revolve about the formal military document MIL-STD-1797A. This standard focuses almost entirely on open loop vehicle characteristics in attempting to ensure that piloted flight tasks can be performed with sufficient ease and precision; that is, the aircraft has satisfactory handling qualities. This approach is quite different from that used to specify the acceptability of automatic flight control systems, where desired closed loop performance and reliability are specified. This occurs despite the fact that most flying

quality deficiencies appear only when the pilot is in the loop acting as a high-gain feedback element (1.22).

This task-related nature of handling qualities is now popularly recognized. However, for modern flight control systems concepts, it is not quite so clear just what the critical pilot tasks will be; therefore, a problem exists in developing design criteria for fly-by-wire and higher order control systems. A complicating factor is the changing nature of air warfare tactics as a result of the changing threat, improving avionics capability, and the increasing functional integration of hardware and aircraft subsystems (1.23).

It is generally true that developing engineering specifications or standards for something so elusive as handling qualities is an art form; however, there is no basis for believing that Cooper-Harper ratings--properly obtained--are not adequate measures of handling qualities. Pilot opinion rating is the only acceptable, available method for handling qualities quantification. In fact, in current literature pilot opinion rating is considered to be synonymous with handling qualities evaluation (1.22, 1.23).

1.4 CONCEPTS OF STABILITY AND CONTROL

In order to exhibit satisfactory flying qualities, an aircraft must be both stable and controllable. The optimum "blend" depends on the total mission of the aircraft. A certain stability is necessary if the aircraft is to be easily controlled by a human pilot. However, too much stability can severely degrade the pilot's ability to perform maneuvering tasks. The optimum blend of stability and control should be the aircraft designer's goal. Flying qualities greatly enhance the ability of the pilot to perform the intended mission when the optimum blend is attained (1.4).

1.4.1 Stability

An aircraft is a dynamic system, i.e., it is a body in motion under the influence of forces and moments producing or changing that motion. In order to investigate aircraft motion, it is first necessary to establish that is can be bought into a condition of equilibrium, i.e., a condition of balance between opposing forces and moments. Then the stability characteristics can be determined. The aircraft is statically stable if restoring forces and moments tend to restore it to equilibrium when disturbed. Thus, static stability characteristics must be investigated from equilibrium flight conditions, in which all forces and moments are in balance. The direct in-flight measurement of some static stability parameters is not feasible in many instances. Therefore, the flight test team must be content with measuring parameters which only

give indications of static stability. However, these indications are usually adequate to establish the mission effectiveness of the aircraft conclusively and are more meaningful to the pilot than the numerical value of stability derivatives (1.4).

The pilot makes changes from one equilibrium flight condition to another through one or more of the aircraft modes of motion. These changes are initiated by exciting the modes by the pilot and terminated by suppressing the modes by the pilot. This describes the classic pilot-in-the-loop flight task. These modes of motion may also be excited by external perturbations. The study of the characteristics of these modes of motion is the study of dynamic stability. Dynamic stability may be classically defined as the time history of the aircraft as it eventually regains equilibrium flight conditions after being disturbed. Dynamic stability characteristics are measured during nonequilibrium flight conditions when the forces and moments acting on the aircraft are not in balance (1.4).

Static and dynamic stability determine the pilot's ability to control the aircraft. While static instability about any axis is generally undesirable, excessively strong static stability about any axis degrades controllability to an unacceptable degree. For some pilot tasks, neutral static stability may actually be desirable because of increased controllability which results. Obviously, the optimum level of static stability depends on the aircraft mission (1.4).

The modes of motion of the aircraft determine its dynamic stability characteristics. The most important characteristics are the frequency, damping, and time constant of the motion. Frequency is defined as the "number of cycles per unit time" and is a measure of the "quickness" of the motion. Damping is a progressive diminishing of amplitude and is a measure of the subsidence of the motion. Damping of the aircraft modes of motion has a profound effect on flying qualities. If it is too low, the aircraft motion is too easily excited by inadvertent pilot inputs or by atmospheric turbulence. If it is too high, the aircraft motion following a control input is slow to develop, and the pilot may describe the aircraft as "sluggish." The aircraft mission again determines the optimum dynamic stability characteristics. However, the pilot desires some damping of aircraft modes of motion. The time constant of the motion is a measure of the overall quickness with which an aircraft, once disturbed from equilibrium, returns to the equilibrium condition (1.4).

Static and dynamic stability prevent unintentional excursions into dangerous flight regimes (with regard to aircraft strength) of dynamic pressure, normal acceleration, and sideforce. The stable aircraft is resistant to deviations in angle of attack, sideslip

and bank angle without action by the pilot. These characteristics not only improve flight safety, but allow the pilot to perform maneuvering tasks with smoothness, precision, and a minimum of effort (1.4).

1.4.2 Control

Controllability is the capability of the aircraft to perform any maneuvering required in total mission accomplishment at the pilot's command. The aircraft characteristics should be such that these maneuvers can be performed precisely and simply with minimum pilot effort (1.4).

1.5 AIRCRAFT CONTROL SYSTEMS

The aircraft flight control system consists of all the mechanical, electrical, and hydraulic elements which convert cockpit control inputs into aerodynamic control surface deflections, or action of other control devices which in turn change the orientation of the vehicle. The flight control system together with the powerplant control system enables the pilot to "fly" his aircraft, that is, to place it at any desired flight condition within its capability.

The powerplant control system acts as a thrust metering device, while the flight control system varies the moments about the aircraft center of gravity. Through these control systems, the pilot varies the velocity, normal acceleration, sideslip, roll rate, and other parameters within the aircraft's envelope. How easily and effectively he accomplishes his task is a measure of the suitability of his control systems. An aircraft with exceptional performance characteristics is virtually worthless if it is not equipped with at least an acceptable flight control system. Since the pilot-control system acts on an aircraft with specific static and dynamic stability properties, it follows that the characteristics of the closed-loop system must be satisfactory.

The control system must meet two conditions if the pilot is to be given suitable command over his aircraft.

1. It must be capable of actuating the control surface.
2. It must provide the pilot with a "feel" that bears a satisfactory relationship to the aircraft's reaction.

There are numerous aircraft control systems designs. However, these systems may be rather simply classified. Aerodynamic controls can be broken down into "reversible" and "irreversible" systems. These systems can be simple mechanical control in which the pilot supplies all of the force required to move the control surface.

This type system is called "reversible" since all of the forces required to overcome the hinge moments at the control surface are transmitted to the cockpit controls. The system may have a mechanical, hydraulic, or some other type of boosting device, which supplies some specific proportion of the control force. Systems of this nature are called "boosted control systems." However, they are still considered "reversible." Even though the force required of the pilot is less than the control surface hinge moments, the force required is proportional to these moments. In other words, the pilot furnishes a fraction of the force required to overcome the hinge moments throughout the aircraft's envelope. The control system is said to be "irreversible" if the pilot actuates a hydraulics or electronic device which in turn moves the control surface. In this system, the aerodynamic hinge moments at the control surface are no longer transmitted to the control wheel or stick. Without artificial feel devices, the pilot would feel only the force required to actuate the valves or sensing devices of his powered control system. Because of this, artificial feel is added which approximates the feel that the pilot senses with the "reversible" system.

A thorough knowledge of the aircraft control system is necessary before a flying qualities evaluation can be planned and executed. The flying qualities test team must be intimately familiar with the control system of the test aircraft. Is the system reversible or irreversible; what type of control surfaces does it have; is a stability augmentation system incorporated, if so, how does it work; is an autopilot included, if so how does it work; are there interconnects between control surfaces (e.g., rudder deflection limited with landing gear up or ailerons limited when the aircraft exceeds a certain airspeed); and what malfunctions effect flying qualities? Total understanding of the test aircraft is necessary in order to get the most information our to a limited flight test program (1.1).

Aircraft control systems will be checked against several paragraphs of MIL-STD-1797A here at the USAF Test Pilot School during student evaluation of data group aircraft.

1.6 SUMMARY

The evaluation of an aircraft's flying qualities incorporates all aspects of the aircraft's stability and control characteristics, control system design, and pilot-in-the-loop handling qualities. The interaction of all these elements determines the ability of a pilot/aircraft/flight control combination to safely and successfully accomplish a mission.

1.7 USAF TEST PILOT SCHOOL CURRICULUM APPROACH

The approach to teaching Flying Qualities will be to:

1. Review the mathematical tools, vectors, matrices and differential equations required for flying quality analysis.

2. Develop the aircraft equations of motion.

3. Examine static longitudinal and lateral-directional aircraft characteristics and steady state maneuvers.

4. Analyze the aircraft longitudinal and lateral-directional dynamics modes of motion.

5. Study specialized flying quality topics such as stall/post-stall/spin and departure, engine-out, and flight controls systems.

6. Discuss advanced flying quality topics. These include the using systems identification techniques for closed loop handling qualities evaluations and extracting stability derivatives from flight test data. Discuss effects of higher order control systems on aircraft flying qualities.

BIBLIOGRAPHY

1.1 Anon., Engineer's Handbook for Aircraft Performance and Flying Qualities Flight Testing, Performance and Flying Qualities Branch, Flight Test Engineering Division, 6510th Test Wing, Air Force Flight Test Center, Edwards AFB CA, May 1971, UNCLASSIFIED.

1.2 Phillips, W.H., Appreciation and Prediction of Flying Qualities, NACA Report 927, National Advisory Committee for Aeronautics, Washington DC, 1949, UNCLASSIFIED.

1.3 Anon., Military Standard, Flying Qualities of Piloted Aircraft, MIL-STD-1797A, 30 Jan 90, UNCLASSIFIED.

1.4 Langdon, S.D., et al., Fixed Wing Stability and Control Theory and Flight Test Techniques, USNTPS-FTM-No. 103, US Naval Test Pilot School, Naval Air Test Center, Patuxent River MD, 1 Jan 75, UNCLASSIFIED.

1.5 Etkin, B., Dynamics of Flight, New York: John Wiley & Sons, Inc., 1959.

1.6 Cooper, G.E., and Harper, R.P., Jr., The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities, NASA TN D-5153, National Aeronautics and Space Agency, Washington DC, April 1959, UNCLASSIFIED.

1.7 Nagy, C.J., A New Method for Test and Analysis of Dynamic Stability and Control, AFFTC-TD-75-4, AFFTC, Edwards AFB CA 93523-5000, May 1976, UNCLASSIFIED.

1.8 Twisdale, T.R., and Franklin, D.T., Tracking Techniques for Handling Qualities Evaluation, AFFTC-TD-75-1, AFFTC, Edwards AFB CA 93523-5000, Apr 1975, UNCLASSIFIED.

1.9 Twisdale, T.R., and Ashurst, T.A., Jr., Systems Identification from Tracking (SIFT), A New Technique for Handling Qualities Test and Evaluation, AFFTC TR-77-27, AFFTC, Edwards AFB CA 93523-5000, Nov 1977, UNCLASSIFIED.

1.10 Westbrook, C.B., The Status and Future of Flying Quality Requirements, AFFDL-FDCC-TM-65-29, Air Force Flight Dynamics Laboratory, Research and Technology Division, Wright-Patterson AFB OH, June 1955, UNCLASSIFIED.

1.11 Anon., Request for Proposal: Lightweight Fighter Prototype Aircraft, F33657-72-

R-0235, Aeronautical Systems Division, Wright-Patterson AFB OH, 6 Jan 72, CONFIDENTIAL.

1.12 Eggers, J.A., and Bryant, W.F., Flying Qualities Evaluation of the YF-16 Prototype Lightweight Fighter, AFFTC-TR-75-15, Air Force Flight Test Center, Edwards AFB CA 93523-5000, July 75, DISTRIBUTION LIMITED.

1.13 Anon., Proposed Lightweight Fighter Prototype, FZP-1401, General Dynamics Convair Aerospace Division, Fort Worth TX, 18 Feb 72, CONFIDENTIAL.

1.14 Perkins, C.D., Development of Airplane Stability and Control Technology, AIAA Journal of Aircraft, Vol 7, No 4, Apr 70, pp. 290-310, UNCLASSIFIED.

1.15 Gilruth, R.R., Requirements for Satisfactory Flying Qualities of Airplanes, NACA TR No. 755, National Advisory Committee for Aeronautics, Washington DC, 1943, UNCLASSIFIED.

1.16 Perkins, C.D., and Walkowicz, A.C., Stability and Control Flight Test Methods, AAT Technical Report No. 5242, Army Air Forces Air Technical Services Command, Dayton OH, 14 Jul 45, UNCLASSIFIED.

1.17 Anon., Stability and Control Requirements for Airplanes, Army Air Forces Specifications C-1815, 1943, and R-1815A, 1945, UNCLASSIFIED.

1.18 Chalk, C.R., et al., Background Information and User Guide for MIL-F-8785B(ASG), "Military Specifications - Flying Qualities of Piloted Airplanes," AFFDL-TR-69-72, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB OH, Aug 69, UNCLASSIFIED.

1.19 Anon., Military Specification, Flying Qualities of Piloted V/STOL Aircraft, MIL-F-83300, 31 Dec 70, UNCLASSIFIED.

1.20 Chalk, C.R., et al., Background Information and User Guide for MIL-F-83300, "Military Specification-Flying Qualities of Piloted V/STOL Aircraft," AFFDL-TR-70-88, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB OH, Mar 71, UNCLASSIFIED.

1.21 Jones, R.L., Major, USAF, Introduction to VSTOL Technology, Lecture notes used at the USAF Aerospace Research Pilot School, Edwards AFB CA 93523-5000, Dec 70, UNCLASSIFIED.

1.22 Hess, R.A., A Pilot Modeling Technique for Handling Qualities Research, Paper

No 80-1624, presented at a workshop on Pilot Induced Oscillations held at NASA Dryden Flight Research Center, Edwards AFB CA 93523-5000, Nov 18-19, 1980, UNCLASSIFIED.

1.23 Smith, R.H., and Geddes, N.D., Handling Quality Requirements for Advanced Aircraft Design: Longitudinal Mode, AFFDL-TR-78-154, Air Force Flight Dynamics Laboratory, Wright-Patterson AFB OH 45433, Aug 79, UNCLASSIFIED.